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(54) Generating apparatus for vehicle

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FIG.1

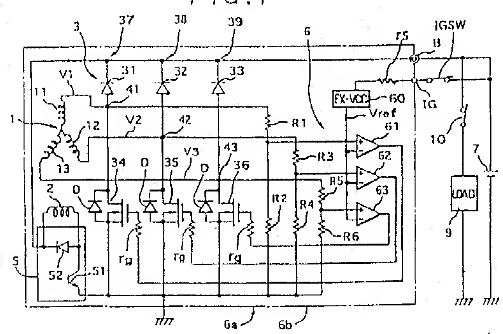

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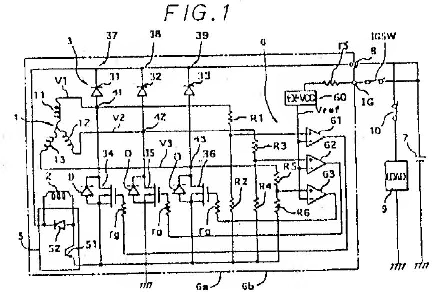
FIG.1



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the giant-pulse-voltage again. Such intermittent operation of the transistor is repeated at a high speed until the giant pulse is suppressed. Even if the giant-pulse-voltage is not generated by turning off the transistor through the high-side element, the giant pulse may be generated by different one of the armature coils. This problem is prevented by providing other armature coils with the short-circuiting means.

The bridge circuit with parasitic diodes energizes the electric load almost continuously. This operation is especially useful to an electric load which is weak in the power stop such as ECU.

According to another feature of the present invention, the transistor used as the low-side element connected to one of the armature coils generating a lowest voltage is turned on. Thus, the transistor clamps a terminal of the one of the armature coils generating the giant-pulse-voltage to suppress the giant-pulse-voltage.

According to another feature of the present invention, the MOS transistor of the low-side elements of the bridge circuit is turned on when one of the armature coils connected thereto generates the giant-pulse-voltage, thereby preventing the giant-pulse-voltage.

Particularly, a constant-voltage-drop-element is connected between the drain and gate of the MOS transistor. The constant-voltage-drop-element does not turn if corresponding armature coil does not generate the giant-pulse-voltage (or generates voltage lower than the second voltage level). When it turns on, the MOS transistor connected thereto turns on to discharge the giant-pulse-voltage to a ground, thereby suppressing the giant-pulse-voltage reaching the electric loads. Therefore, the giant-pulse-voltage is substantially suppressed only by adding a simple circuit, and the withstand-voltage between the drain and gate and the punch-through voltage between the drain and source of the MOS transistor.

According to another feature of the present invention, the second voltage level which is the threshold level for detecting the giant-pulse-voltage is between 2 - 3 times as high as the battery voltage, thereby preventing an excessive voltage reaching the electric loads connected to the B-terminal.

According to another feature of the present invention, the second voltage level is higher than a voltage which is the forward-voltage-drop of the diode plus the first voltage level. Therefore, the armature coils operating in the normal condition are not short-circuited, thereby preventing an excessive voltage from reaching the battery and the electric loads.

According to another feature of the present invention, the transistor is the SiC-MOS transistor which has much smaller on-resistance than the Si-MOS transistor. Therefore, it can rectify the AC current with small loss. The SiC-MOS transistor has high thermal withstand-characteristics and a high thermal conductivity and, therefore, the transistor does not break down due to heat caused while it suppresses the giant-pulse-voltage.

According to another feature of the present invention, the high-side element or low-side element is a parallel circuit composed of a bipolar transistor or IGBT and a junction diode connected in the direction to rectify the output voltage of the generator. In this case, the giant-pulse-voltage is suppressed in the same manner as above by short-circuiting the armature coil through the bipolar transistor or IGBT and the junction diode on the same side but connected to a different one of the armature coils, thereby suppressing the giant-pulse-voltage with ease.

According to another feature of the present invention, the transistor for suppressing the giant-pulse-voltage is not completely turned on when the giant-pulse-voltage is generated but is controlled by a pulse-width modulated signal to have an average conducting ratio, thereby preventing over-heating and break-down of the transistor.

According to another feature of the present invention, the short-circuiting means keeps the transistor conductive for a certain period after the giant-pulse-voltage is detected. Therefore, the short-circuiting is maintained until the giant-pulse-voltage is attenuated and the electromotive force in the armature coil lowers to a certain level, thereby preventing the giant-pulse-voltage.

According to another feature of the present invention, the MOS transistor connected to one of the armature coils generating the giant-pulse-voltage is controlled while the giant-pulse-voltage is being generated to suppress the giant-pulse-voltage as far as the corresponding armature coil energizes the electric load.

Thus, when the battery is disconnected , the giant-pulse-voltage is not applied to the electric loads while the electric supply to the electric loads is continued.

According to another feature of the present invention, the MOS transistors are used in both high-side and low-side elements. Therefore, the MOS transistor is turned on when the giant-pulse-voltage is generated to attenuate the giant-pulse-voltage so that the voltage between the source or drain and the gate of the MOS transistor does not become too high to break the insulation layer of the gate. As a result, the leading-phase-control or high-speed switching-control can be carried out by the MOS transistor-type bridge circuit, thereby improving reliability thereof without using elements of large-current-capacity.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and characteristics of the present invention as well as the functions of related parts of the present invention will become clear from a study of the following detailed description, the appended claims and the drawings. In the drawings:

Fig. 1 is a circuit diagram of a generating apparatus according to a first embodiment of the present invention;

circuit 6a divides the phase voltage V2 of the armature coil 12 and the voltage-dividing-circuit 6a divides the phase voltage of the armature coil V3. A reference numeral 60 is a constant voltage circuit for providing a reference voltage Vref which corresponds to the second voltage level by a voltage supplied from the battery 7 through a resistor r5 from an ignition switch IGSW.

The comparators 61 - 63 compare divided voltages of the phase voltages V1 - V3 with the reference voltage respectively and supply a high level signal to the gates of the MOS transistors 34 - 36, which are the low-side elements of the three-phase full-wave rectifier 3, through gate resistors rg for cutting high-frequency waves, thereby turning the transistors on.

The operation of excessive-voltage-control circuit 6 is described next.

When no giant-pulse-voltage is generated, the output voltage of the voltage-dividing-circuit 6a is lower than the reference voltage Vref so that the output voltage of the comparator 61 - 63 becomes low, thereby causing the transistor 34 - 36 to be non-conductive.

If one of the terminals of the battery 7 in the charging operation is disconnected or if the output current of the three-phase full-wave rectifier 3 suddenly decreases, a giant-pulse-voltage is generated in one of the armature coils in generation and is sent to the B terminal through the rectifier 3.

If the giant-pulse-voltage becomes high enough to make one of the comparators 61 - 63, which corresponds to the one generating the giant-pulse-voltage, generate the high level signal, the corresponding one of the MOS transistor 34 - 36 is turned on. Consequently, a current flows from the coil generating the giant-pulse-voltage to a ground line so that the corresponding MOS transistor clamps the coil generating the giant-pulse-voltage. As a result, the excessive giant pulse sent from the high-side element for the phase coil generating the giant pulse to the electric load 9 is suppressed so that bad influence on the electric load 9 and the battery 7 can be suppressed. Because the voltage of the armature coil generating the giant-pulse-voltage is suppressed, the withstand voltage of the MOS transistor, which is one of the low-side elements connected to the armature coil generating the giant-pulse-voltage, can be lowered.

When a divided voltage of the giant-pulse-voltage becomes lower than the reference voltage Vref, the comparator corresponding to the armature coil generating the giant-pulse-voltage produces the low level signal so that the MOS transistor corresponding to the armature coil generating the giant-pulse-voltage is turned off. As a result, the full-wave rectifier 3 returns to the normal rectifying operation.

If the comparator 61 detects the giant pulse and produces the high level signal to turn on the MOS transistor 34, the output voltage of the armature coil 11 generating the giant pulse suddenly lowers and, subsequently, the comparator 61 produces the low level signal to turn off the transistor 34. Then, the output voltage of the armature coil 11 increases again, thereby causing the comparator 61 to produce the high level signal, which turns on the transistor 34. Thus, on-off operation of the comparator 61 and the MOS transistor 34 and resultant intermittent current of the diode 31 of the high-side element follows. The MOS transistor 34 is switched on and off at a high frequency, and the giant-pulse-voltage is controlled so that the output voltage VB becomes a second voltage (two or three times as high as the battery voltage). As a result, all the semiconductor elements are prevented from the breakdown and excessive voltage to be applied to electric loads is prevented.

When one of the MOS transistors of the armature coil generating the giant-pulse-voltage (e.g. MOS transistor 34) is turned on, at least one negative phase voltage V2 or V3 is generated by the remaining armature coils 12 or 13, so that the parasitic diode D of at least one of the MOS transistors 35 and 36 connected to the remaining armature coils 12 and 13 is turned on to allow a circulating current, thereby dissipating the magnetic energy accumulated by the magnetic circuit including the armature coils 11 - 13 of the generator 1 and reducing the giant-pulse-voltage.

Fig. 2 shows the giant pulse in the output voltage of the rectifier 3. In Fig. 2, a one-dot-chain line indicates a giant-pulse-voltage when no control is provided; a solid line indicates a generated voltage when the giant pulse voltage is suppressed to two times as high as the battery voltage; and a broken line indicates a generated voltage when the giant-pulse-voltage is suppressed slightly higher (about 14 V) than the forward voltage drop of the diodes for the high-side elements (or about 0.7V) plus the battery voltage.

(Second Embodiment)

A second embodiment of the present invention is described with reference to Fig. 3.

This embodiment is the same as the first embodiment except that the excessive-voltage-control circuit 6 of the first embodiment is replaced with an excessive-voltage-control circuit 600, which has three series circuits of constant-voltage-diode 311 and a resistor rg. Each of the series circuits is connected between the main electrode (or drain) and the gate of the MOS transistors 34 - 36 (low-side elements).

When the giant-pulse-voltage is generated, the constant-voltage-diode 311 of the armature coil generating the giant-pulse-voltage breaks down and the gate of the MOS transistor generating the giant-pulse-voltage is charged to a level higher than the threshold level after a while decided by the time constant of an integrating circuit composed of the resistor rg and the gate capacity. Consequently, the MOS transistor is turned on and suppresses the giant pulse voltage in the same manner as the first embodiment. Because only a small amount of current flows through the constant-voltage-diodes 311, they can be made compact. When no giant-

operates in the same manner as the circuit shown in Fig. 5 is added to each of the armature coils. In this case, the output voltages of the AND circuits 621 - 623 are applied respectively to the diode 87.

In this embodiment, the comparator 85 produces the high level signal to turn on the MOS transistor 33 in Fig. 4 when the generated voltage Vc becomes higher than the battery voltage or the output voltage V0 of the three-phase full-wave rectifier 3.

In the first and second embodiments, each of the high-side elements 31 - 33 is composed of a junction diode, and each of the low-side elements is composed of a MOS transistor and the parasitic diode thereof. However, either one of the following elements can be used as the high-side or low-side element: (a) MOS transistor having the parasitic diode, (b) junction diode, (c) IGBT with a parallel junction diode, (d) bipolar transistor having a parallel junction diode and (e) SiC-MOS transistor having the parasitic diode.

It is noted that either the high-side elements 31 - 33 or the low-side elements must use the transistors. The high-level signals of the comparator 85 and the AND gates 621 - 623 are set to be high enough to turn on the MOS transistors for the high-side elements.

The PWM (pulse width modulation)-control system can be introduced to suppress heating of the transistors which are used for the high-side elements 31 - 33 or the low-side elements. The PWM-control system can be composed of an oscillator for generating a constant-frequency-signal-voltage of a suitable duty ratio, an AND circuit taking in the constant-frequency-signal-voltage and the collector voltage of the transistor shown in Fig. 1 or the voltage to turn on all the MOS transistors 34 - 36. The PWM-control system is added to the circuit 5 to control the MOS transistors 34 - 36 according to the AND signal of the AND circuit. The circuit structure is simple and obvious, and further description thereof is omitted.

The heat-resistant SiC-MOS transistors are preferably used to cope with the temperature rise while the giant-pulse-voltage is controlled.

(Fifth Embodiment)

A fifth embodiment of the present invention is described with reference to Fig. 8.

The difference in this embodiment from the second embodiment (shown in Fig. 3) is resistors r21 connected between each gate of the MOS transistors 34 - 36 and a ground.

The features of this embodiment is described below.

In the second embodiment, if the constant diode 311 corresponding to the armature coil 13 generating the giant-pulse-voltage breaks down and the gate of the MOS transistor 36 for the armature coil 11 generating the giant-pulse-voltage is charged, the MOS transistor 36 is not turned off as long as the giant-pulse-voltage is not lower than the threshold level which is lower than the battery voltage. Therefore, the normal output voltage is not generated immediately. In this embodiment, the resistors 21 for gate-discharging-path can prevent the above problem. The gate voltage applied to the gate of the MOS transistor 36 is $(V3 - Vz) \times r21/(rg + r21)$, if the generated voltage is V3. If the gate voltage is higher than the threshold level, the MOS transistor 36 is turned on. Vz is a breakdown voltage of the constant diode 311.

(Variation)

A variation of the fifth embodiment is described with reference to Figs. 9A and 9B.

Fig. 9A shows the same portion as shown in Fig. 8 except for the constant voltage diode 311. In this case, the voltage dividing circuit is composed of the resistors rg and r21. When the voltage divided by both resistors rg and r21 becomes the threshold level of the MOS transistor 36, the transistor 36 is turned on. For example, if the output voltage V3 is turned on at 18 volt with the threshold level of the MOS transistor being 3 volt, the dividing ratio of the resistors rg and r21 is 6 : 1.

Fig. 9B shows the same portion as shown in Fig. 8 except that the constant voltage diode 311 is replaced with a pnp transistor 400. A reference character rb is a resistor. If the giant pulse is generated, the transistor 400 is turned on to turn on the MOS transistor 36. The emitter voltage of the transistor 400 is set twice as high as the battery voltage. An inverting-amplifying-circuit can be replaced with the pnp transistor 400.

(Sixth Embodiment)

A sixth embodiment of the present invention is described with reference to Fig. 10.

The circuit according to this embodiment has a bridge circuit composed of N-channel MOS transistors instead of the high-side element 31 - 33 of the rectifier 3 of the first embodiment (shown in Fig. 1) and a controller 53 included in the generation-control-circuit 5 for controlling the MOS transistors 31 - 36. The controller 53 is supplied with the B voltage, and is driven to operate when the IG voltage becomes high. The controller 53 controls the transistor 51 so that the B voltage becomes a certain voltage (first voltage level) and controls the MOS transistors 31 - 36 successively according to the output signals of the comparators 61 - 63 to rectify the generated phase-voltages V1, V2 and V3. A parasitic diode (not shown) is connected between the source and drain of each one of the MOS transistors 31 - 36 with the cathode thereof connected to the drain and the anode thereof connected to the source (P-well). A circuit for controlling a pair of transistors for one phase (e. g. MOS transistor 31 and 34) of the MOS transistors 31 - 36 is shown in Fig. 11. The operation of the circuit for the phase voltage V1 is described next.

When the giant pulse is not generated in the normal rectifying operation, the comparator 61 produces the

turn on the MOS transistor 31 and turn off the MOS transistor 34 to supply the electric load 9 with the generated voltage V1. When the MOS transistor 31 is turned on and the MOS transistor 34 is turned off, the giant-pulse-voltage is generated because the giant-pulse-power is not sufficiently dissipated. However, the high-speed-switching-operation makes the comparator 64 produce the high level signal to turn off the MOS transistor 31 and turn on the MOS transistor 34, thereby reducing the giant pulse voltage and preventing it from reaching the electric loads. Fig. 14 shows voltage waves applied to various parts shown in Fig. 12.

In conclusion, according to this embodiment, the electric load 9 is energized at a voltage controlled by the reference voltage Vref' even after the giant-pulse voltage is generated.

This embodiment can be applied to any circuit other than the full-MOS-transistor-type bridge circuit 3 shown in Fig. 10. The holding circuit 601 of this embodiment can be replaced with a temporary holding circuit such as a monostable-multi-vibrator. In this case, the high level signal is held for a period (hundreds milli sec.) long enough for the giant-pulse-voltage to be attenuated. Thus it is possible to return to the normal control operation after the holding operation is cancelled. The comparator 61 - 63 can be replaced with an A-D converter combined with a software for the microcomputer which produses the excessive voltage signal if the reliability thereof is as sufficiently high as the comparators 61 - 63.

In the foregoing description of the present invention, the invention has been disclosed with reference to specific embodiments thereof. It will, however, be evident that various modifications and changes may be made to the specific embodiments of the present invention without departing from the broader spirit and scope of the invention as set forth in the appended claims. Accordingly, the description of the present invention in this document is to be regarded in an illustrative, rather than restrictive, sense.

Claims

1. A generating apparatus for a vehicle including an AC generator (1) having a field coil (2) and armature coils (11, 12, 13) driven by an engine, a bridge circuit (3) having high-side rectifying elements (31, 32, 33) and low-side rectifying elements (34, 35, 36) connected between each terminal of said armature coils (11, 12, 13) and a battery (7), a control unit (6, 600, 601) for controlling a part of said high-side and low-side elements (31-36), a voltage regulator (5) for regulating the output voltage of said bridge circuit (3) to a first voltage level, wherein

   said control unit (6, 600, 601) comprises:

   an excessive-voltage-detecting-means (61-66, 311) connected to said armature coils (11, 12, 13) for producing an excessive-voltage signal when a giant-pulse-voltage generated in said armature coils (11, 12, 13) exceeds a second voltage level which is a certain-level higher than said first voltage level; and

   a short-circuiting means (53, 31-33, 34-36), connected to said excessive voltage-detecting-means (61-66, 311) and said armature coils (11, 12, 13), for selectively short-circuiting a part of said armature coils (11, 12, 13), thereby suppressing said giant-pulse-voltage by turning on a portion of said rectifying elements according to said excessive-voltage signal.

2. A generating apparatus as claimed in Claim 1, wherein

   said short-circuiting means (53,31-33, 34-36) turns on one of the low-side rectifying elements (34, 35, 36) of said bridge circuit (3).

3. A generating apparatus as claimed in Claim 1, wherein

   each of said low-side rectifying elements (34, 35, 36) of said bridge circuit (3) comprises a MOS transistor;

   said control unit (6, 600, 601) comprises a constant-voltage-drop element (311) connected between a main terminal of said MOS transistor connected to said generator and the gate thereof; and

   said excessive-voltage-detecting-means (61-66, 311) comprises said constant-voltage-drop element (311) for supplying a gate current when said output voltage exceeds a second voltage level.

4. A generating apparatus as claimed in Claim 1, wherein

   said short-circuiting means (53,31-33, 34-36) turns on one of said high-side rectifying elements (31, 32, 33) connected to a terminal of said armature coils (11, 12, 13) in the negative potential according to an output signal of said excessive-voltage-detecting-means (61 - 66, 311).

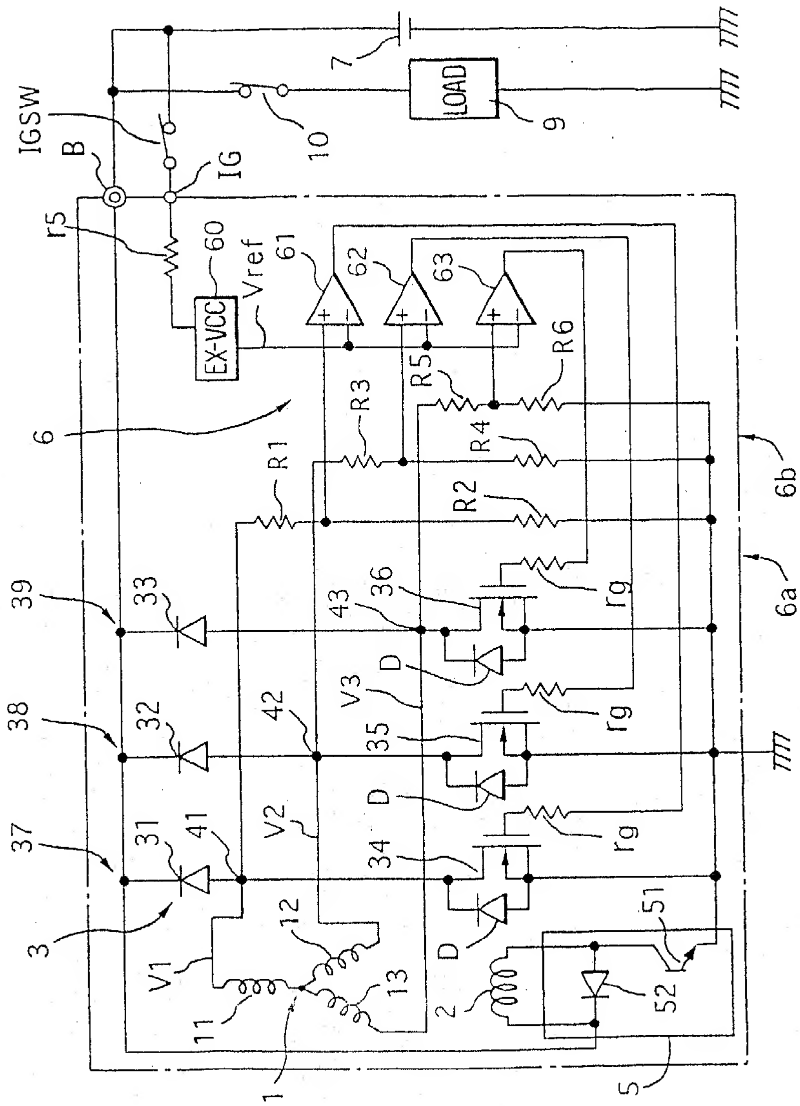
5. A generating apparatus as claimed in Claim 1, wherein said second voltage level is not lower than two times and not higher than three times as high as the normal voltage of said battery (7).

6. A generating apparatus as claimed in Claim 1, wherein

   said second voltage level is higher than a voltage which is a forward-voltage drop of a junction diode (31-33) plus said first voltage level.

7. A generating apparatus as claimed in Claim 1, wherein

   at least one of said high-side rectifying elements (31, 32, 33) and low-side rectifying elements (34, 35, 36) comprises SiC-MOS transistors.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Vref
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62
63
6
R1
R2
R3
R4
R5
R6
rg
6a
6b
39
38
37
33
32
31
43
42
41
36
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V1
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V3
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2
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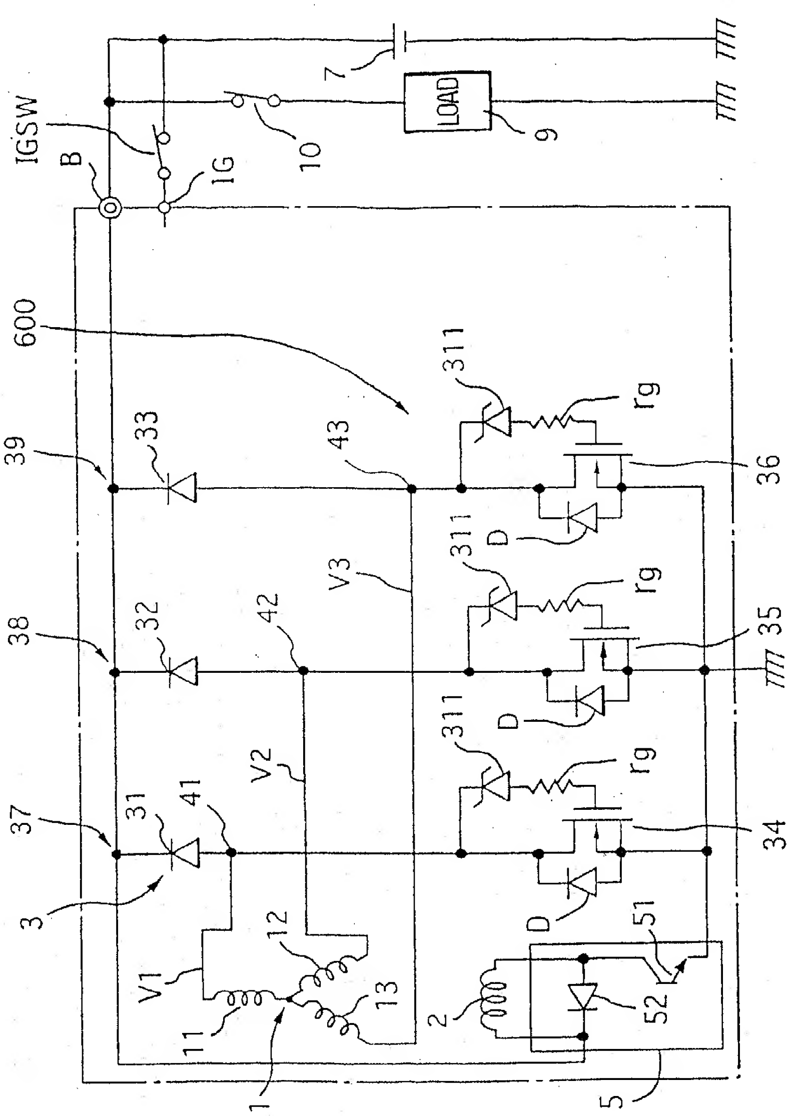
5

F I G. 1

FIG. 3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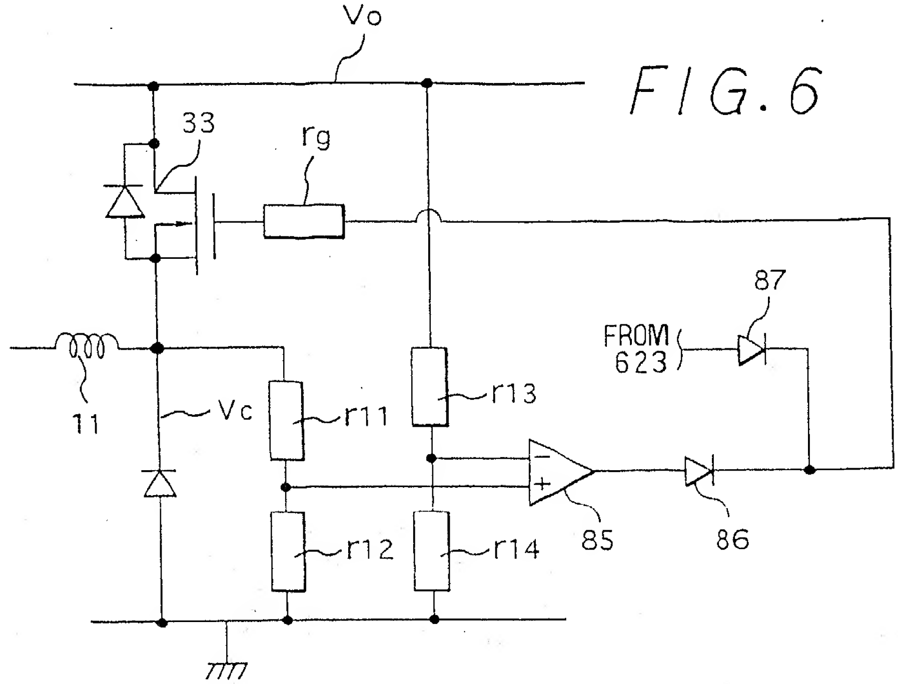


FIG. 6

FIG. 9A

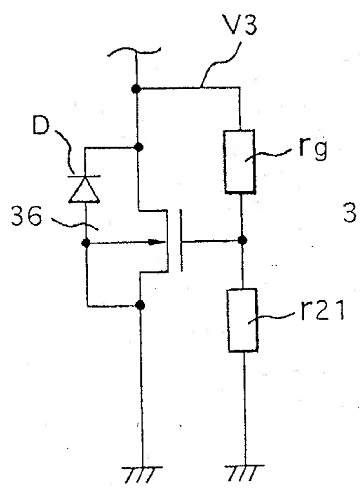
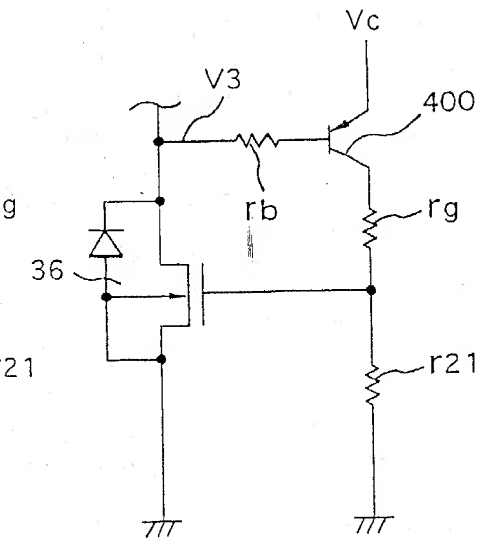
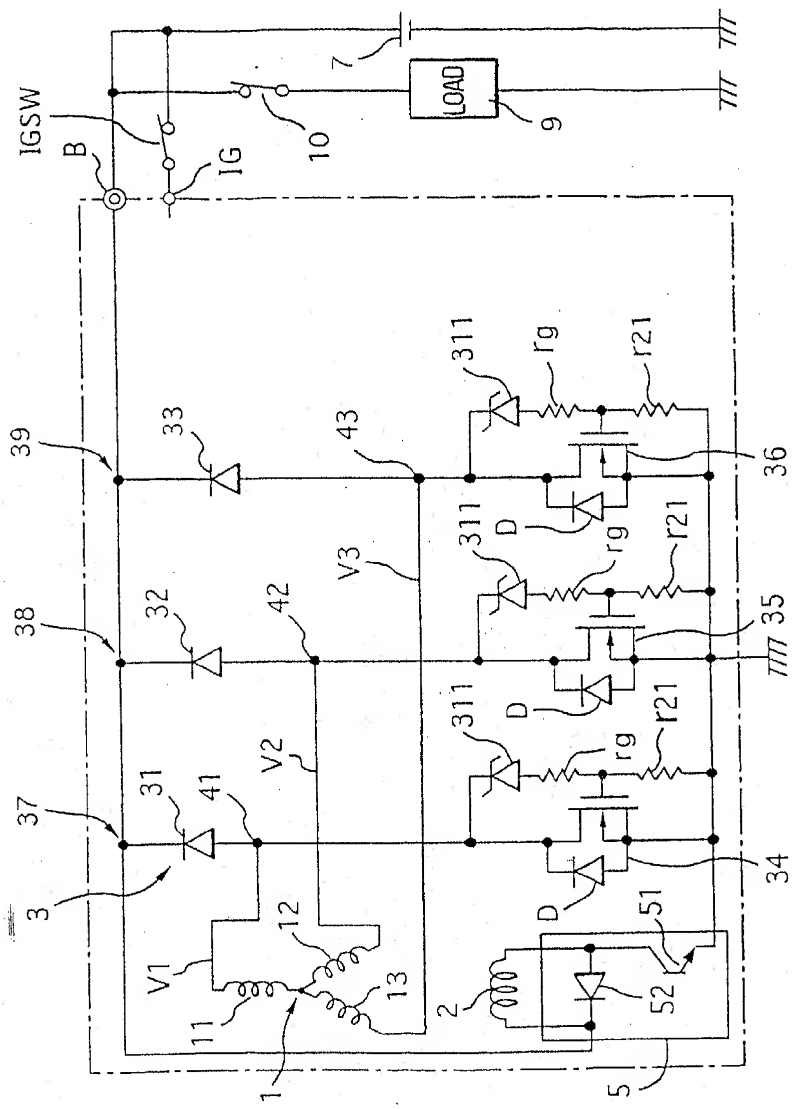


FIG. 9B

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42
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V3
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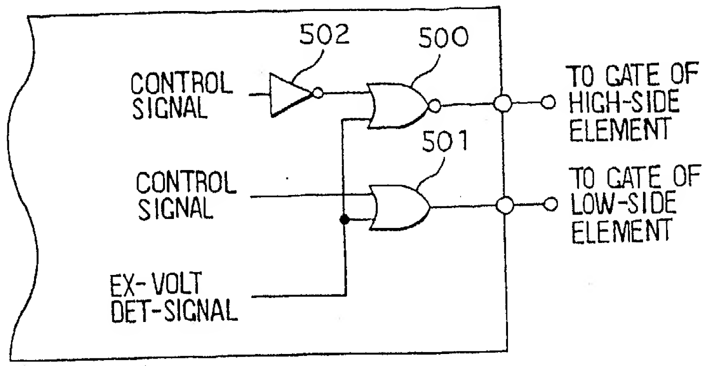
36
3
1
11
12
13
2
51
52
5

F/G. 8

FIG. 11


502
500
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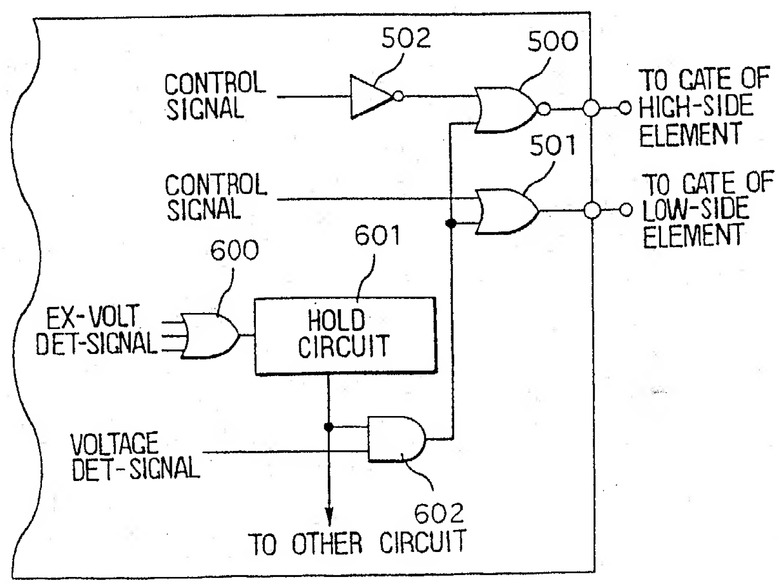
TO GATE OF HIGH-SIDE ELEMENT
501
CONTROL SIGNAL
TO GATE OF LOW-SIDE ELEMENT
EX-VOLT DET-SIGNAL

FIG. 13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501
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601
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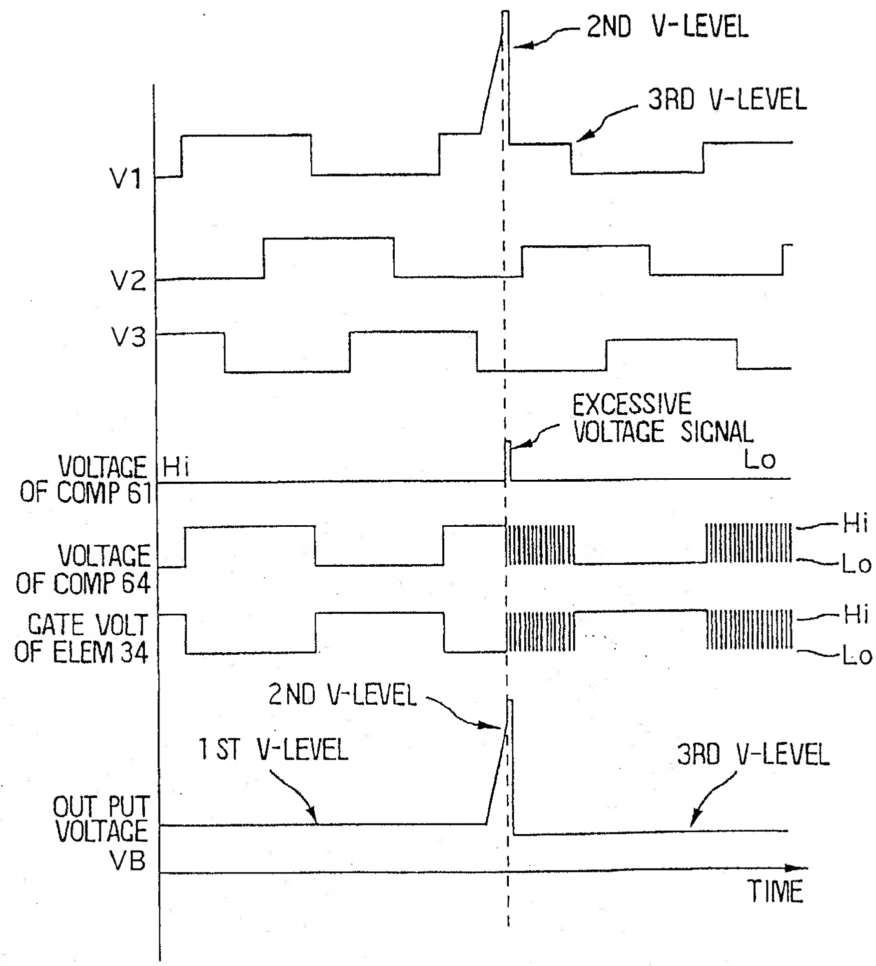
HOLD CIRCUIT
VOLTAGE DET-SIGNAL
602
TO OTHER CIRCUIT

FIG.14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3RD V-LEVEL
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V2
V3
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Hi
Lo
VOLTAGE OF COMP 64
Hi
Lo
GATE VOLT OF ELEM 34
Hi
Lo
2ND V-LEVEL
1 ST V-LEVEL
3RD V-LEVEL
OUT PUT VOLTAGE VB
TIME